The Analysis and Software Infrastructure Status/Plans

PAC Meeting, Fermilab

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for the SBN Collaborations

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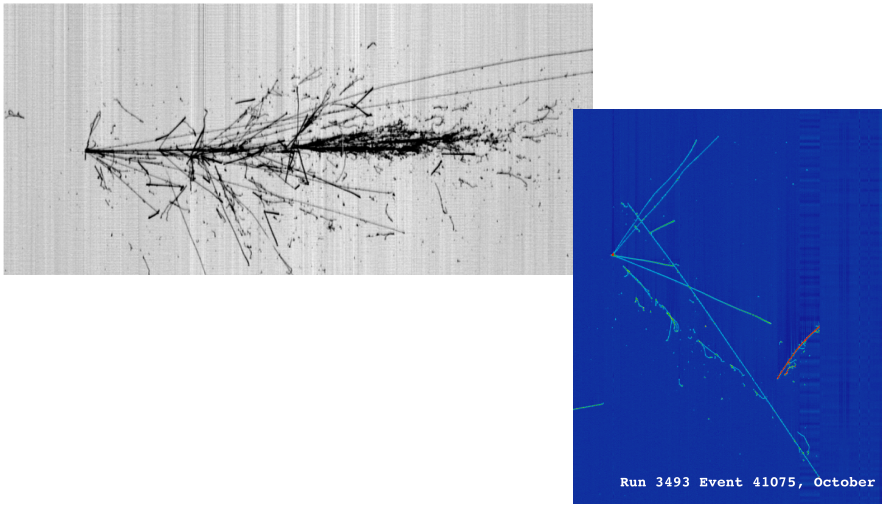
Outline: SBN Efforts toward Coordinating Plans

- Ongoing analysis Efforts and SBN coordination across the three experiments – Current Status and Plans
  - *Software development:*
    - Common LAr software environment
  - *Analysis efforts:*
    - Surface operation and cosmic background mitigation, Task Force on Cosmic Ray Mitigation for SBN Detectors
    - Physics of the BNB upgrade, study oscillation sensitivities for different beams configurations (upgrades of the BNB beamline)
  - *Technical coordination:*
    - DAQ and online systems
    - Cosmic ray taggers
    - Photon detectors



Science Goals of the SBN Program

- Directly follow-up on the **MiniBooNE neutrino anomaly** by utilizing the LArTPC technology to determine the composition of the observed excess as electrons or photons (Phase I)

- Apply the advantages of the LArTPC technology and *multiple detectors at different baselines* to the question of high-Δm^2 **sterile neutrino oscillations**, testing current allowed oscillation parameters at $\geq 5\sigma$ (Phase II)

- Study ν-Argon interaction physics using **millions of events** from both the Booster and Main Injector neutrino beams at Fermilab

- Further **develop the LArTPC technology** toward applying it at very large scales for long-baseline physics in DUNE

The SBN Proposal

Scientific proposal and conceptual design report for the SBN program (Jan 2015)

A Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in the Fermilab Booster Neutrino Beam

Submitted jointly by ICARUS, MicroBooNE and SBND (LAr1-ND)
http://arxiv.org/abs/1503.01520

Part I: SBN Physics Program

Part II: Near Detector Conceptual Design

Part III: T600 Design and Refurbishing

Part IV: Infrastructure and Civil Construction

Part V: Booster Neutrino Beam

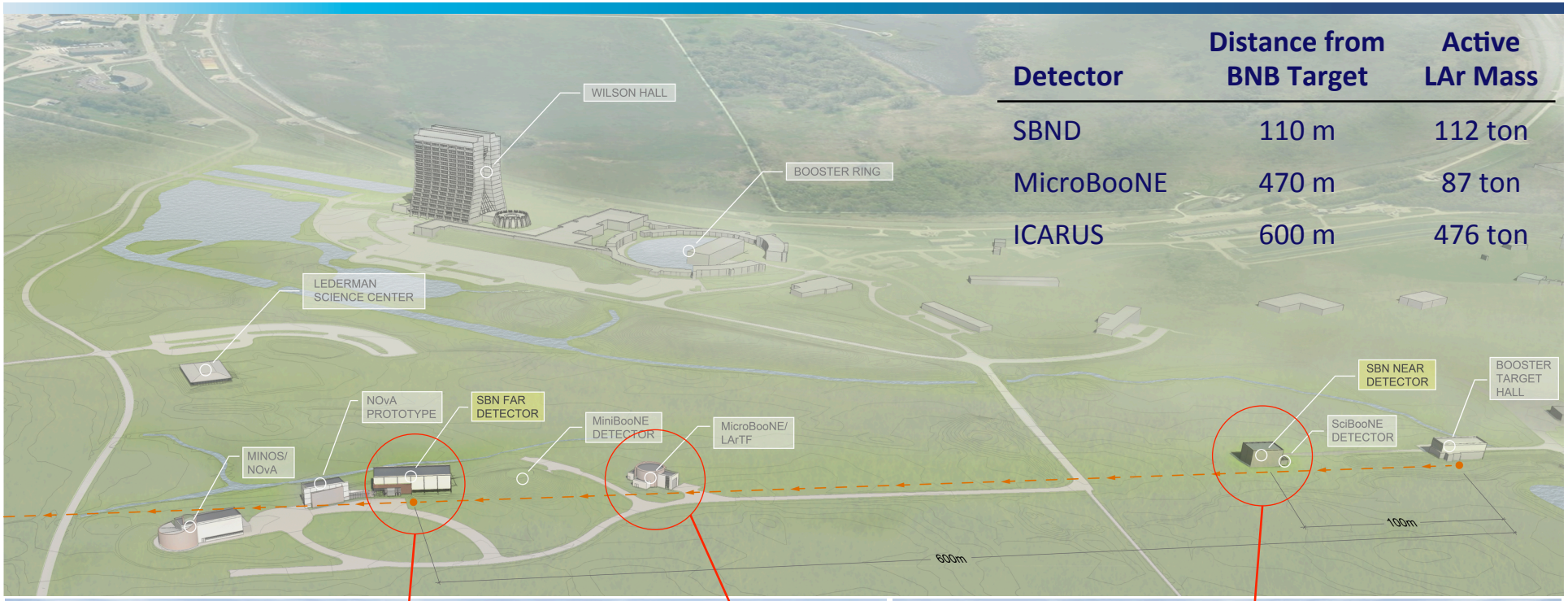
Part VI: Coordination and Schedule

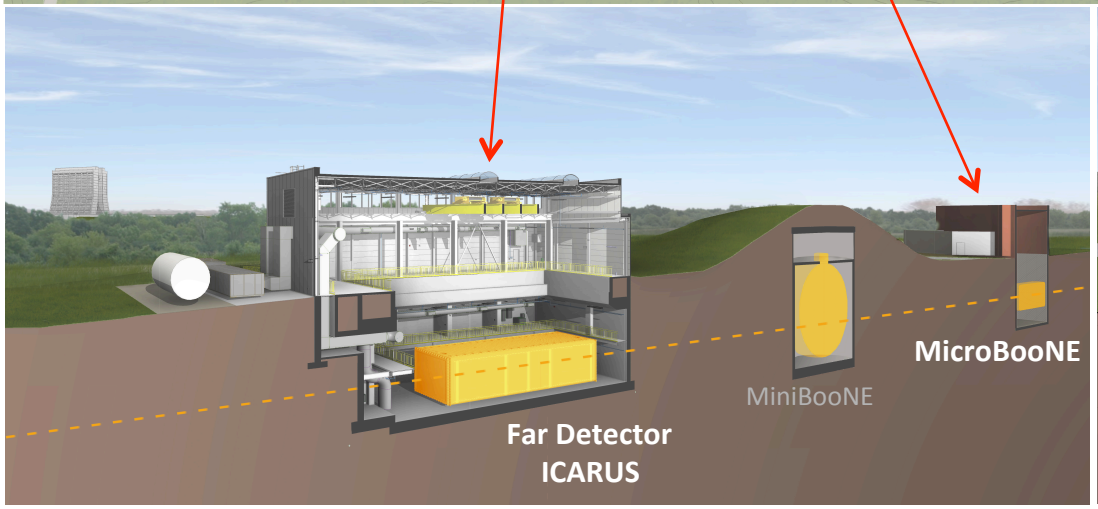
218 authors from 22 US and 23 non-US institutions

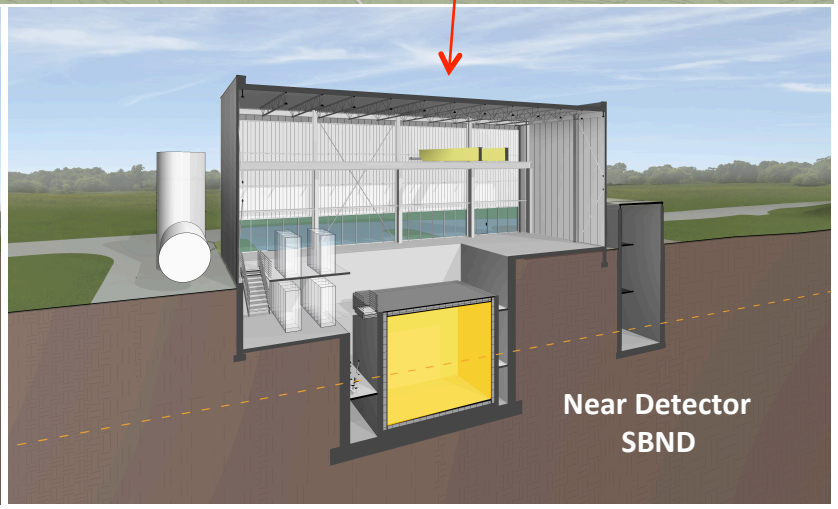
Collaborations have all continued to grow through 2015

The Three-Detector SBN Program

Detector	Distance from BNB Target	Active LAr Mass
SBND	110 m	112 ton
MicroBooNE	470 m	87 ton
ICARUS	600 m	476 ton



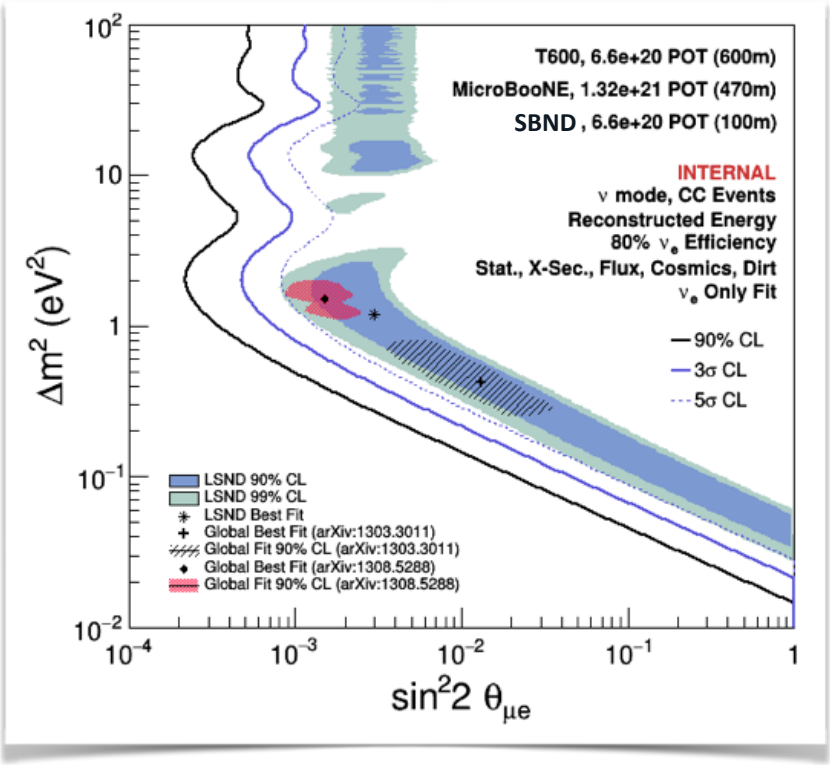




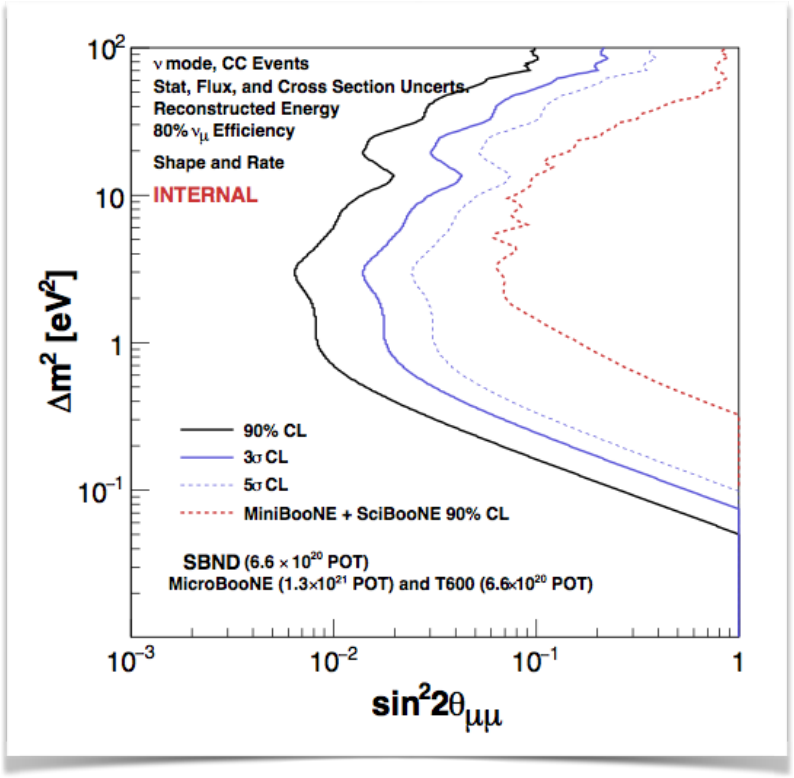
Physics Reach of the SBN Program

- Oscillation sensitivity of the SBN program has been evaluated in a joint effort by three collaborations
- Sensitivities are based on full simulations of all known backgrounds and systematic uncertainties

ν_e Appearance



ν_μ Disappearance



Since January 2015

- Development of the SBN physics proposal
  - *Spearheaded by a five member Task Force representing FNAL, CERN, and the three collaborations as well as a set of Working Groups with co-conveners and members from each of the collaborations*
  - *4 WGs: flux and systematics, cosmics, cryogenic infrastructure, civil construction*
- Following the proposal
  - *SBN Executive Board consisting of collaboration spokespersons and SBN Program Coordinator formed to facilitate continued communication*
- With Stage 1 approval granted after the January 2015 PAC, focus of collaborations has been on *detector design, construction, and operation* - Excellent technical progress in 2015!
- Analysis and software development has continued in parallel with both short- and long-term aims
  - *Emphasis tends to be where input is needed for detector or program design… e.g.→*

Joint Software development

Analysis Software Coordination

- LArSoft provides a common software infrastructure for the sharing of reconstruction and simulation codes used by different liquid argon TPC experiments
  - *ArgoNeuT, MicroBooNE, LArIAT, SBND, DUNE, etc. use the LArSoft framework*
  - *ICARUS developed their own analysis software for the Gran Sasso physics run before start of the LArSoft project*
  - *ICARUS reconstruction workshop held at CERN in July included LArSoft experts from Fermilab and reconstruction developers from MicroBooNE*
- *Steering Group* of experiment spokespeople/software experts (formed over the past 12 months)
  - *Meets with LArSoft team ~monthly to drive developments, prioritize work, and plan for the future*
- LBNC also working with the groups – to receive reports on assessment, planning and future work for software and analysis for the LArTPC-based experiments

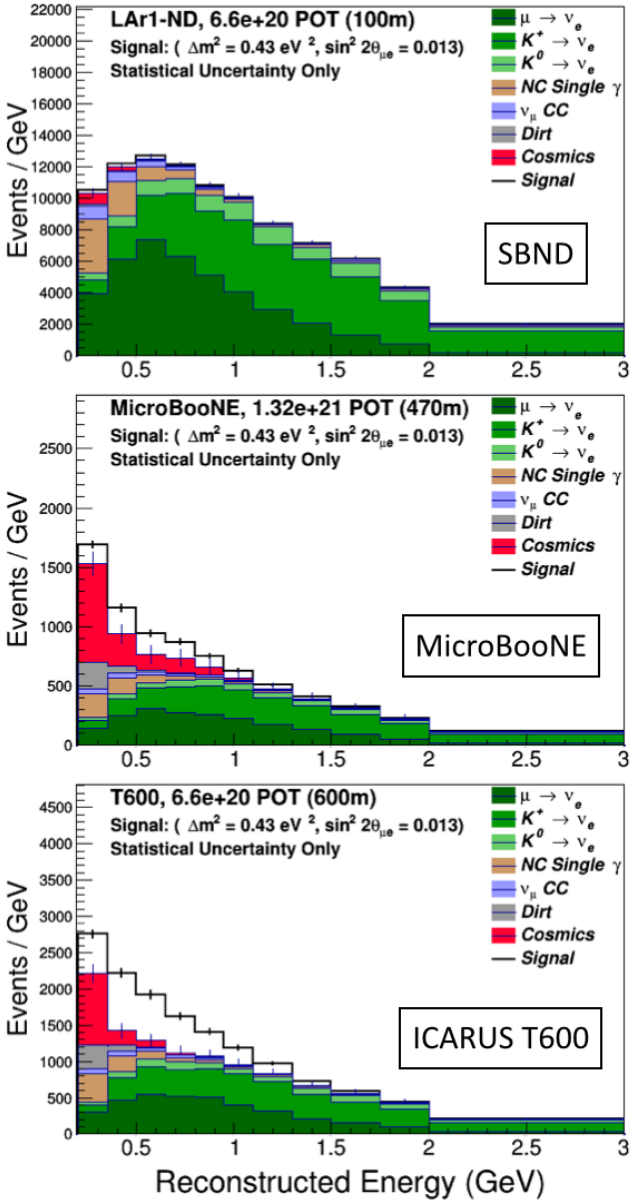
Analysis Software Coordination

- Software workshop with all stakeholders held at Fermilab in October
  - *Organized and attended by Fermilab and CERN computing experts together with representatives from SBN (MicroBooNE, ICARUS, and SBND), DUNE, and LArIAT*
  - *Reviewed status of reconstruction development among the groups*
  - ***Primary goal**: To define requirements for a LArTPC software platform that will support the analysis needs of LArTPC experiments over the next ~decade*
  - *Requirements document now in draft, authored by workshop participants*
    - https://cdcvs.fnal.gov/redmine/projects/lartpc-requirements/repository/revisions/master/entry/new-document/requirements.pdf
  - *Some examples: **i)** physics algorithm performance, **ii)** ability to use multiple physics algorithms in end-to-end analysis of data, **iii)** increased functionality of event visualizations, **iv)** enable effective use of multi-core and new computer hardware technologies, **v)** ease of use and distribution for international collaborations, **vi)** inclusion of new external software components such as event generators and hadronic simulation codes*
- Next step is to plan future work based on published requirements – again to involve all participants

Joint Analysis Efforts

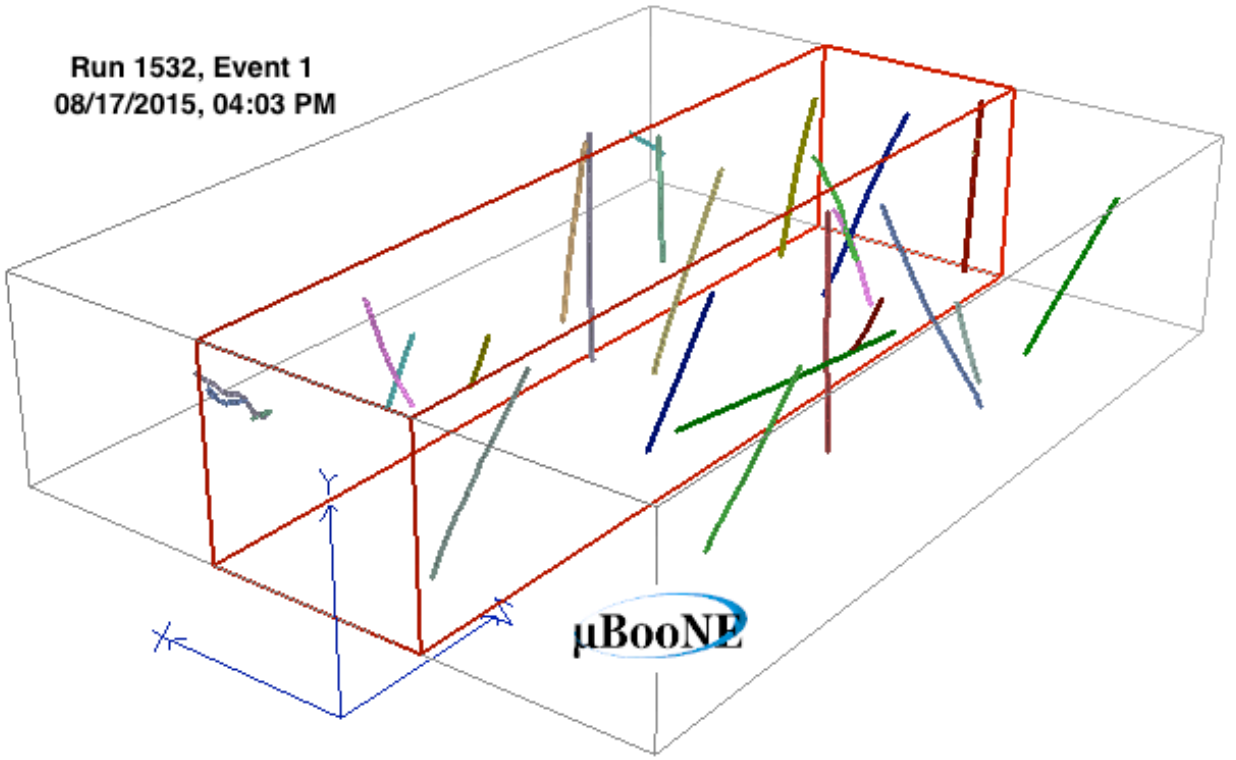
- *Mitigation of cosmogenic backgrounds*
- *Physics of the BNB upgrade*

Mitigation of Cosmogenic Backgrounds



- The problem: 1000x longer charge drift time than the beam spill time!

1.6 μs beam spill vs. 1-2 ms TPC drift time



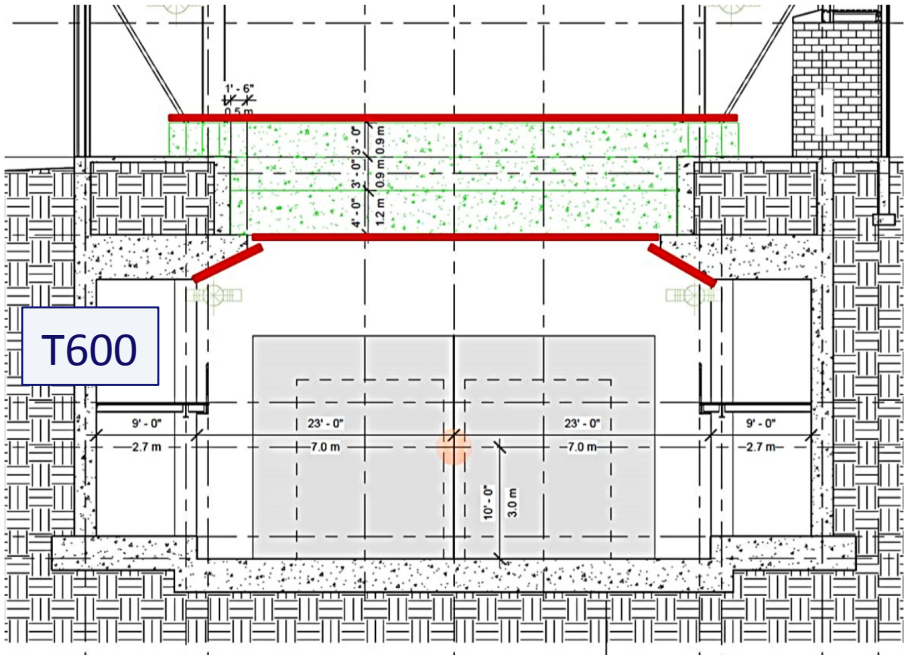
MicroBooNE cosmic data with 3D reconstruction!

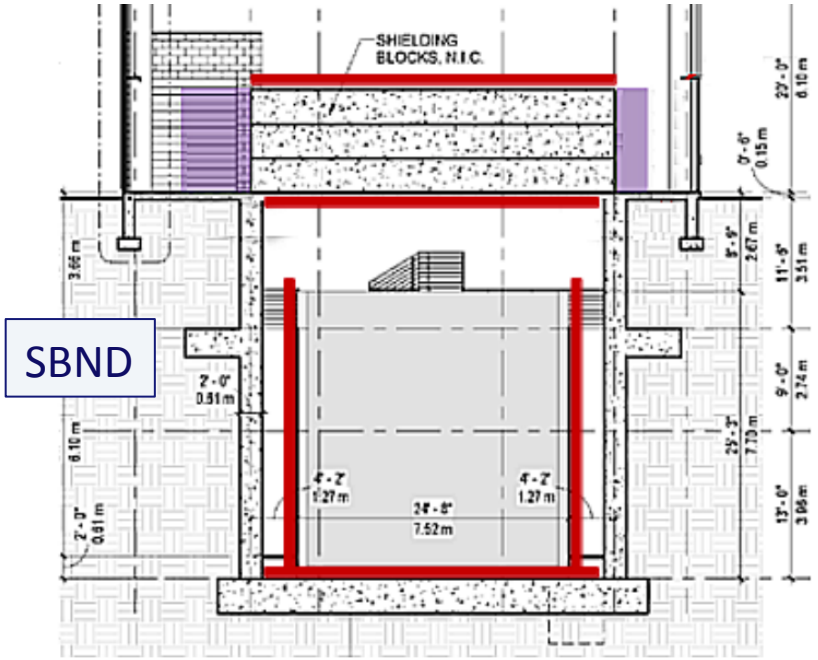
Mitigation of Cosmogenic Backgrounds

- Both the near and far detector buildings have been designed to accommodate up to 3m of concrete shielding directly above the detectors and MicroBooNE has proposed adding overburden
- Overburden provides significant rejection power for many ν_e-like backgrounds induced by cosmic rays other than muons
  - *Near 100% reduction of **primary** protons, neutrons, pions, and gammas that enter the TPCs without OB*
  - *Modest increase in **secondaries** generated in OB (e.g. 1% increase in secondary protons and 7% increase in secondary neutrons with 3m concrete OB according to a recent SBND simulation study)*
- This leaves photons generated by cosmic muons near or inside the detector as the primary source of cosmogenic backgrounds in the ν_e analysis

Cosmic Ray Tagger Design

- The SBN proposal assumed a 3m concrete overburden and cosmic ray tagger system for both the near and far detectors and MicroBooNE has recently proposed installing a tagger system
- SBND and MicroBooNE tagger are being designed and constructed
- ICARUS tagger is being designed





SBN Task Force on Cosmic ray Mitigation

- The three collaborations performed simulations for the SBN proposal to study the impact of cosmic rays, the need of cosmic-ray tagger systems and overburden
- Since then--continued effort to compare/validate those results and push on new required studies
- Joint *Cosmic Ray Mitigation Task Force for SBN Detectors* formed in Nov. 2015 to define the requirements and implementation of the overburden and cosmic ray tagger systems for the SBN detectors
  - *Conveners: one representative for each experiment*
  - *Preliminary report next month*

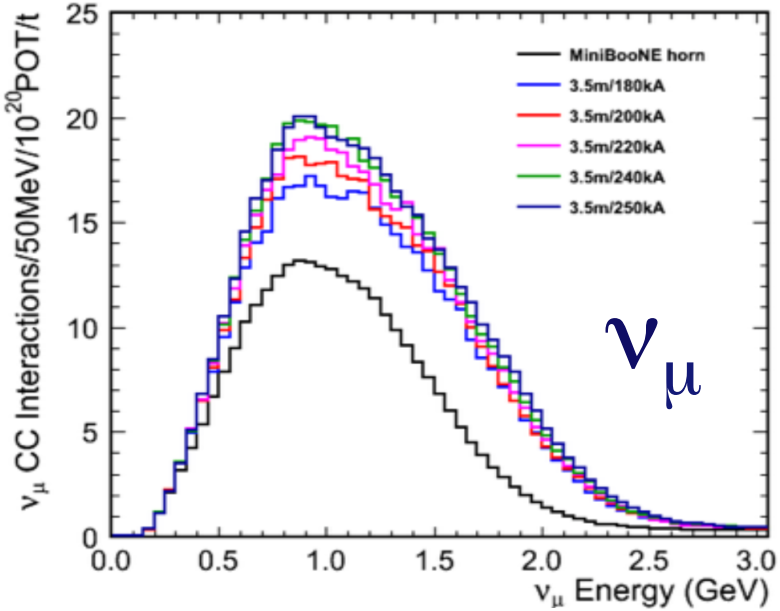
***Joint Task Force** charged with assimilating available information and performing any new analysis needed to address specific questions related to overburden and CRT systems*

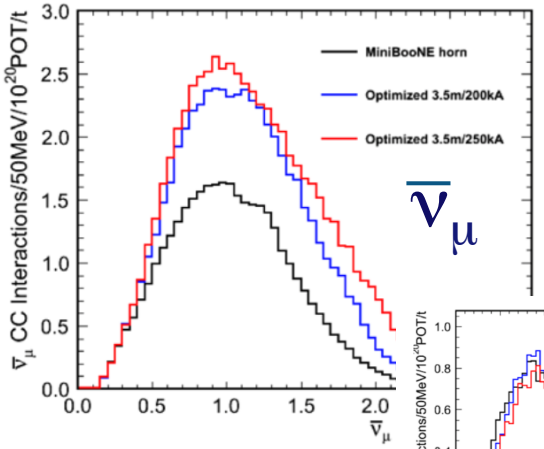
Improving Collaboration

- The Task Force build on substantial joint effort for the three-detector proposal
- Main questions that are now being addressed jointly by all the three experiments for each of the detectors
  - *Accurate description of building/detector geometry*
  - *Impact and required thickness (1m, 2m, 3m) of the overburden*
  - *Cosmic tagger system (CRT) configuration and performance requirements (spatial granularity, time resolution, number of layers)*
  - *Additional rejection from the cosmic tagger systems relative to internal light collection system*
  - *Impact of activity from secondary particles (from cosmic rays and beam interactions) on cosmic taggers*
  - *Identify areas where common technical solutions could be used for SBND, MicroBooNE and ICARUS-T600*
    - Can the already designed SBND readout electronics be used for all detectors?
    - Can a common scintillator strip size/configuration be used for at least part of the systems?
    - …
- Two joint meetings
  - *Working on protocol for internal-documents sharing*

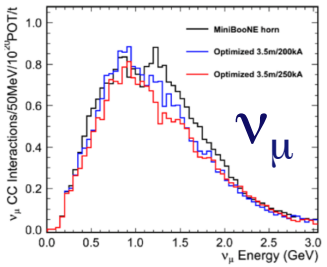
Booster Neutrino Beam Improvements

- Far detector statistics are key to ν_e appearance sensitivity
  - *(Detector mass) x (Neutrino flux) x (Time)*
- Possible BNB upgrade paths:
  1. *Increase focusing efficiency of target/horn system*
     - Optimize horn length, inner conductor, and current
  2. *Increase rate at which horn system is capable of running*
     - Booster can operate at 15 Hz, existing horn at 5 Hz (limited by mechanical integrity and power supply)
- Detailed study carried out by design team at FNAL; conclusion: gains up to **~1.8× in event rate** possible with longer horn design and upgraded power supply





antineutrino mode running



Upgrades of the BNB beamline

- Following one the recommendations at the December SBN Program Director's Progress Review:
  - *"Perform simulations to clarify the additional sensitivity reach from the new flux spectrum, quantify at what POT systematics start to dominate, and the dependence on assumptions about NC pi0 rejection and cancellation of errors in the near/far ratio."*
- Charge SBND, MicroBooNE, ICARUS and BNB experts with addressing the physics reach for different beams configurations (by May 2016)

Technical coordination

Technical Coordination

- Cosmic Ray Tagger Systems
  - *Common solutions in scintillator tracker design and readout electronics*
- DAQ
  - *Lots of activity involving SBND, MicroBooNE, and ICARUS DAQ experts to consider common DAQ software solutions, data formats, etc.*
  - *One-day SBN-DUNE workshop held in November to explore possible synergies within DAQ and readout electronics.*
- Photon Detection
  - *SBND working with ICARUS on PMT-based photon detection system*
  - *SBND to use same PMTs, 8" Hamamatsu R5912*
  - *Plan to send SBND PMTs to CERN for wavelength shifter coating and performance testing/characterization in same facility used for ICARUS tubes*
  - *Working together to decide on similar electronics and DAQ system*

Summary: SBN Analysis/Software coordination

- SBN detectors have made enormous technical progress in 2015
  - *MicroBooNE is running with beam! SBN phase-I now operational!*
  - *ICARUS T600 refurbishment is progressing well and on schedule at CERN*
  - *SBND TPC is in final design phase, construction to begin in early 2016*
  - *Civil construction on-going*
  - *Improved beam designs being explored*
- Coordinating plans
  - *Software development, coordinated analysis approach/efforts and technical coordination*

Well on our way to an exciting SBN physics program!